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date: September 30, 1971

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from: B. A. Gropper

subject: Scientist Team Performance During an Auroral Expedition in NASA's CV-990 Airborne Laboratory - Case ~~105-9~~ 236

(NASA-CR-122854) SCIENTIST TEAM PERFORMANCE DURING AN AURORAL EXPEDITION IN NASA'S CV-990 AIRBORNE LABORATORY (Bellcomm, Inc.) 38 p

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ABSTRACT

Behavior and performance patterns of a multidisciplinary scientific team were studied during NASA's 1968 CV-990 auroral expedition. This series of high-altitude Arctic flights combined real stresses, motivations, rewards and operational problems for the participating scientists, and offered an opportunity for exploratory study of how such teams might function in future space missions.

This report summarizes the backgrounds of the mission members, the planning of the scientific program, the roles of the scientist and management-support teams, their living and working environments, and the behavior-performance patterns observed.

The results indicate:

a) Differences in personal backgrounds and mission objectives are reflected in group behavior patterns. Team members with similar backgrounds and mission roles are more likely to associate during off-duty periods, and tend to select each other for similar future missions.

b) Conflicts may develop between a scientist's motivations and mission roles. These conflicts may reflect the need to coordinate with other experiments and the delegation of some planning capabilities to a management team whose scientific background may be less expert than his own.

c) Sources of dissatisfaction within a mission are more likely to be aspects the scientist team considers to be important and flexible (e.g., schedules), than those that may be physically stressful, but less subject to control (e.g., weather constraints).

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MEMORANDUM FOR FILE

1.0 INTRODUCTION

Future advanced manned space systems will differ significantly from those in past programs. Many factors directly involving the human beings will change, including: increased sizes of flight teams; increased diversity of their scientific and technical backgrounds and flight objectives; increased mission durations; closer approximations to accustomed earth-based living and working environments; and decreased pre-flight periods for the selection and training of individuals and mission teams. In anticipation of these developments, NASA's current programs include a variety of research studies on complex man-systems-environment factors, aimed at optimizing the Agency's capabilities to design and support such future systems.

During January-March, 1968, teams of scientists, technicians and support personnel in NASA's CV-990 Airborne Laboratory conducted two series of flights for high-altitude auroral observations from Fort Churchill, Canada. Because of this expedition's similarities to potential manned space missions, NASA concurrently studied the scientific team's behavior and performance characteristics under operational conditions. A Bellcomm representative, N. Zill, was invited to participate in the first two weeks of flights and conduct psychological studies of: (a) the performance of scientific activities in remote settings with limited resources, (b) approaches to predicting and monitoring the effective performance of such activities, and (c) related social dynamics of isolated technical groups (Reference 1).

The results were only partially analyzed at the time, due to commitments in support of NASA's programs in Tektite I and II. Since these unpublished materials are still of interest, the writer reviewed them with Dr. Zill, now with the University City Science Center in Philadelphia, in order to assess what had been done, analyze and evaluate the results, and identify their potential relevance to current interests.

This memorandum reports the results. The following sections summarize the behavior and performance evaluations, with comments on their implications for future studies and future operational programs. They cover:

(1) the rationale for the present investigative approach,

(2) the characteristics of the mission teams, their working and living environments, and relevant mission events,

(3) the results of the present behavioral analyses, and their implications for the planning and management of future space missions with teams of scientists.

2.0 METHODS AND MEASURES

Under the sub-Arctic field conditions of the present study, conventional laboratory techniques could not be used for several reasons. In order to place the results in the appropriate perspective, it is important to understand the factors that governed the design and conduct of the psychological investigations in this field situation.

2.1 Investigative Constraints

Several concurrent requirements had to be satisfied. One set related to fundamental criteria for scientific studies with human subjects. These included: (a) identification of potentially significant variables in these situations and their investigative priorities; (b) estimation of the analytic sensitivity of alternative methods for measuring them; (c) review of the data from prior studies in similar situations; etc. That is, these requirements covered the basic planning of what to measure, how, and why.

Another set related to more specific problems. These included: (a) acquisition of all field data had to be feasible by one man for both the ground and inflight situations; (b) all needed materials had to be prepared within approximately two weeks' lead-time, and (c) all observations had to be compatible with unhampered performance of the primary auroral investigations and mission support activities.

This second set of "real-world" constraints was important for two reasons. First, it severely limited the investigators' ability to design and implement a comprehensive coverage of all factors related to the study's objectives--and the present data necessarily reflect those limitations. Second, in making comparisons with other studies or projections to future investigations and operational support situations, these investigative methods and measures would not necessarily be selected if other sets of options are available.

The net effect is that this study must be considered only exploratory. These flights provided an opportunity to develop preliminary identifications of potential problems with minimal additional investment and without interference with other scientific objectives. Further work will be required to define the degree to which these findings hold for future space conditions.

2.2 Investigative Methods

Direct quantitative measures of levels of quality for scientific performance and research have so far proven elusive. This has been especially true with short-term measures. Prior investigations of scientific teams in remote and hostile environments have typically emphasized indirect measures of performance, by sampling objective and subjective data on the participants (e.g., activity logs and interviews), rather than direct measures of task variables or physiological parameters (e.g., task speed, power consumption, heart rate, etc). The reasons are twofold--the complexities of conceptual definition and modeling, and the feasibility of non-interfering long-term measurement under operational conditions.

Thus, even though measures of time, for example, are relatively standard for most activities, it is extremely difficult to assess whether an astronomer who takes a given amount of time to investigate topic A is also a better or worse astronomer than another who may take less time tor two studies of topic B. Similarly, it is exceedingly difficult to try to identify and measure each individual's concurrent activities over extended periods, without excessive instrumentation or interference with those activities.

The dominant research strategy in prior studies, therefore, has been first to identify how individual and group behaviors and attitudes might interact within classes of laboratory and field situations, and then obtain and compare sets of events and activity records with the participants' backgrounds and reactions (see, for example, References 3-6). In the present study a participant-observer lived and worked alongside the other mission members, gathering in-situ information on their scientific and support activities during the mission. By combining this with real-time and post-mission feedback from the participants, plus the pre-mission development of the program, it was hoped to be able to improve our understanding of how these program elements affect one another.

Figure 1 provides a schematic outline of the relatively separate evolution and development of the NASA CV-990 aircraft and its support facilities, the auroral instruments and experimental procedures, and the activities of the individual scientists during the pre-mission periods. The basic objective in the design of the airborne laboratory was to make it a flexible, general purpose, reusable facility that would be able to accommodate a wide variety of existing instruments, without extensive modification to them and with relatively short lead-times. In addition, it would require little or no special training or flight selection of the scientist team-members to assure they could safely use it (Reference 7).

For these initial auroral flights, the potential inclusion of an investigation of scientific team performance was established in the final pre-mission period. Approximately two weeks' lead-time was available for all preparations. All selection of team members and overall program planning had been completed before this study could be begun. Accordingly,

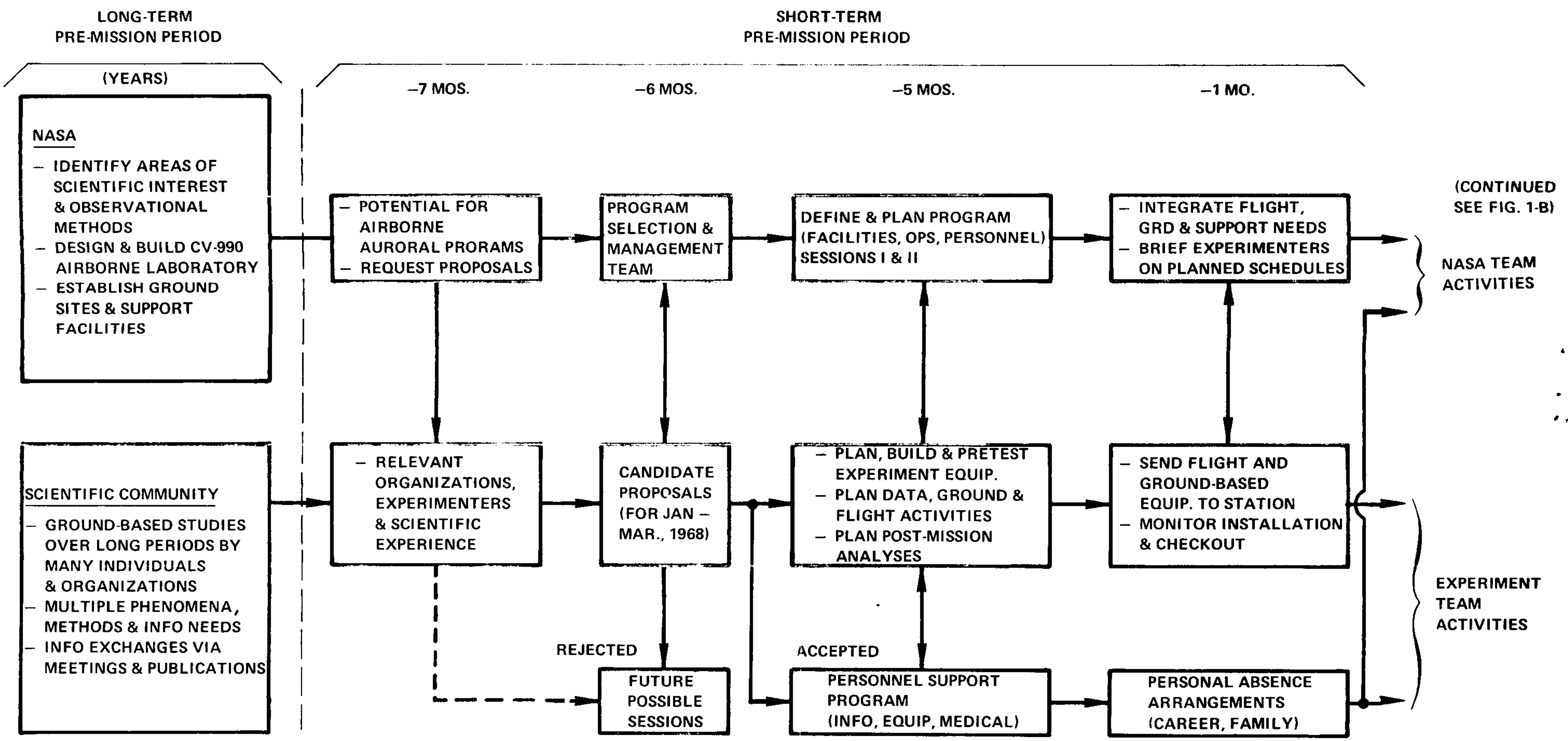

FIGURE 1 - EVOLUTION OF SCIENTIFIC PROGRAM AND ROLES OF PARTICIPANTS
(A. PRE-MISSION PERIODS)

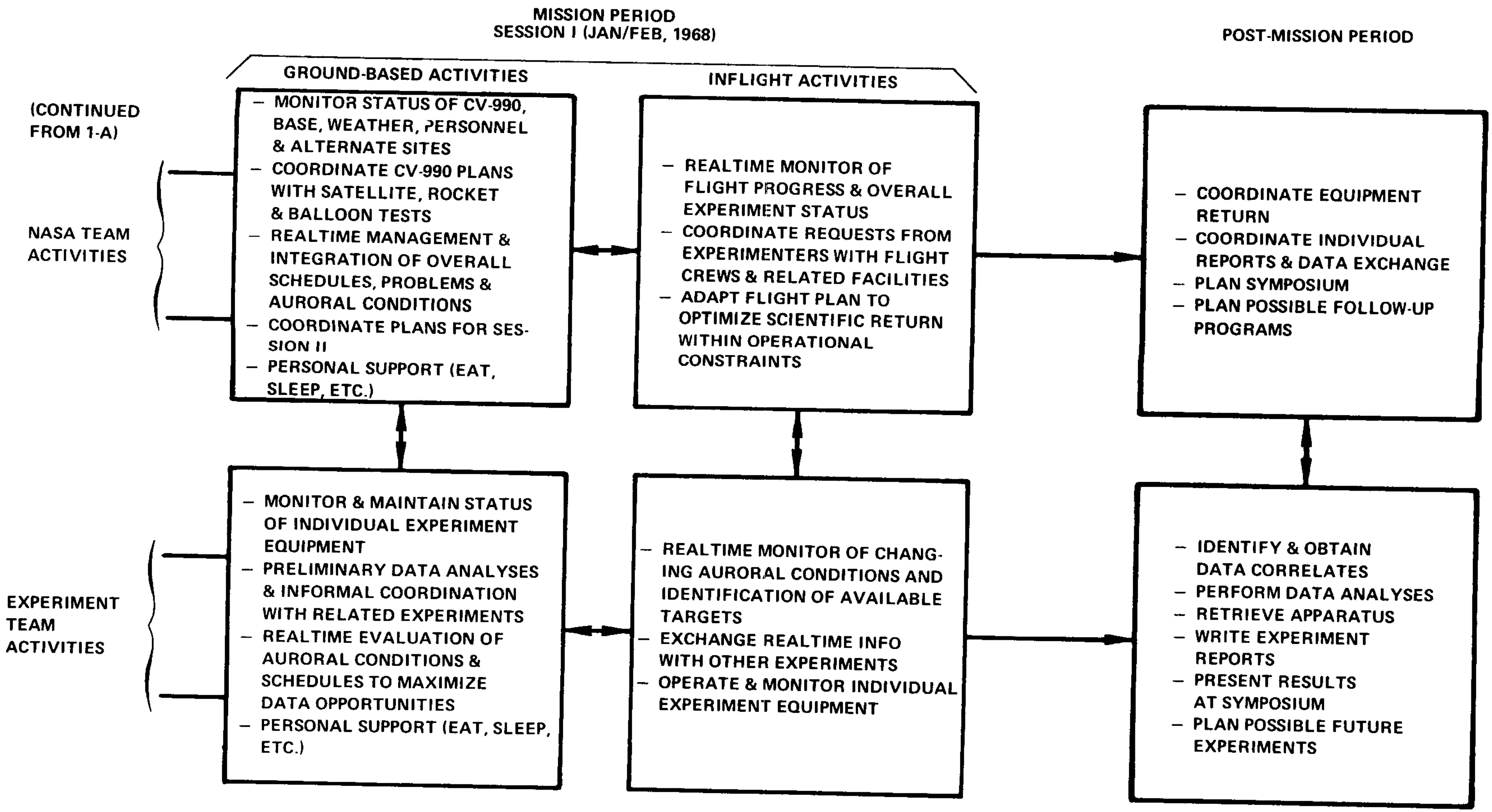

FIGURE 1 – CONTINUED (B. MISSION AND POST-MISSION PERIODS)

the types of pre-mission information and background profiles that might have been taken earlier had to be obtained during the first days of the actual mission period.

The following sections examine the relations indicated in Figure 1 in greater depth. They discuss the background profiles of the mission members, the roles of the scientist and management-support teams, their living and working environments, and the behavior-performance patterns observed, and the overall mission results.

3.0 RESULTS

The flight program succeeded in making the desired high-altitude observations and the auroral findings and related phenomena have been reported. (See Appendix A). The results of primary interest here are the behaviors and support activities that contributed to those findings. That is, given those successful products, we are interested in knowing more about the processes that helped produce them.

3.1 Working and Living Environments

The complex combinations of factors that significantly affect the probabilities of success in large-scale scientific activities may be conveniently grouped into three broad categories: (1) the physical and psychological environments, (2) the personal and interpersonal characteristics of the participants, and (3) the particular sets of phenomena or events they encounter. In actual operational situations, of course, their inter-relationships cannot be readily isolated.

Table I summarizes the major characteristics of the sub-Arctic working and living conditions within this study. The primary points of interest here are that these conditions are generally less demanding than those that have existed in space missions to date, but more demanding that the participants' usual home and laboratory environments.

For example, referring to Table I-A, the 15 scientists had to work within a flying laboratory that permitted "shirt-sleeve" operations, similar to those being planned for future space facilities but modified by the aerodynamic accelerations and time-profiles of present jet aircraft. The instruments

TABLE I

SUMMARY OF WORKING AND LIVING ENVIRONMENTS

A. FLIGHT CONDITIONS —

VEHICLE:	NASA CV-990 AIRBORNE LABORATORY (4-ENGINE JET)
SAMPLE PERIOD:	JANUARY 16 – FEBRUARY 10, 1968
NO. OF FLIGHTS:	PLANNED (13), ACHIEVED (9)
FLIGHT HOURS:	PLANNED (64.0), ACHIEVED (34.25)
OPERATIONAL RANGE:	~3300 N. MI; ~7 HRS. MAXIMUM DURATION
OPERATIONAL ALTITUDES:	CEILING ~12.5 KM (~40K FEET)
OPERATIONAL SPEEDS:	270 KNOTS (MIN.) AT 1.5 KM 500 KNOTS (MAX.) AT 12.2 KM
OPERATIONAL TIMES:	~2.0 HRS. AT 12.2 KM TO 6.3 HRS. AT 10.1 KM
CABIN CONDITIONS:	PRESSURIZED TO 2.4 KM AT CEILING TEMPERATURE: 18°C TO 23°C (± 1°C) RELATIVE HUMIDITY: ~10%
STABILIZATION:	AUTOPILOT (± 2° NOM.), PLUS GYROSTABILIZED EQUIPMENT AND IMAGING SENSORS
COMMUNICATIONS:	CONTINUOUS MULTI-CHANNEL INTERCOM, PLUS 2-WAY GROUND CONTACT
VISIBILITY:	STANDARD SEAT-SIDE WINDOWS, 14° AND 65° ELEVATION VIEWING PORTS
PERSONNEL:	P. I. AND EXPERIMENT SUPPORT: 10 – 18/FLT. FLIGHT CREW AND SYSTEMS SUPPORT: 6 – 14/FLT. MANAGEMENT AND COORDINATION: 2 – 5/FLT. PASSENGERS: 0 – 3/FLT. – TYPICAL COMPLEMENTS: 19 – 34 PEOPLE (40 MAX. CAPACITY)

B. GROUND BASE CONDITIONS—

BASE STATION:	FORT CHURCHILL RESEARCH RANGE, HUDSON BAY, CANADA (7° BELOW ARCTIC CIRCLE)
WEATHER CONDITIONS:	SUB-ARCTIC WINTER SURFACE TEMPERATURES TO –30°F SURFACE WINDS TO 50 MPH
ACCESSIBILITY:	YEAR-ROUND AIR, RAIL, WATER AND SURFACE-ROAD ACCESS
COMMUNICATIONS:	CONTINUOUS TWO-WAY MULTIPLE RADIO AND TELEPHONE LINKS; BUSINESS AND PERSONAL USE
PERSONNEL:	TYPICALLY SEVERAL HUNDRED U.S. AND CANADIANS MILITARY-CIVILIAN/SCIENTIFIC-TECHNICAL-SUPPORT
PERSONNEL SUPPORT:	FACILITIES AND USE GROUPED BY MILITARY-CIVILIAN RANK AND WORK ASSIGNMENTS
a) LIVING:	DORMITORIES, WITH 1 – 4 MAN ROOMS, LOUNGES, CENTRAL HEAT, TOILET AND BATH FACILITIES
b) DINING:	MILITARY-STYLE MESS HALLS; CONVENTIONAL FOODS
c) RECREATION:	GYM FACILITIES, MOVIES, RADIO, BOOKS, AND SOCIAL INTERACTIONS (NO BROADCAST TELEVISION)
d) SHOPPING:	FULL RANGE OF ITEMS IN POST EXCHANGES
e) HEALTH:	INFIRMARY WITH MEDICAL-SURGICAL SERVICES ON BASE

TECHNICAL SUPPORT:

a) FULL FACILITIES AND PERSONNEL FOR FLIGHT EQUIPMENT INSTALLATION/MAINTENANCE/STORAGE

b) FULL FACILITIES FOR GROUND-BASED EXPERIMENTS AND DATA SUPPORT (ROCKET AND BALLOON LAUNCH SITES) they used for their auroral observations were essentially "off-the-shelf" models, including magnetometers, photometers, riometers, and spectrophotometers. The experimental procedures were essentially the same ground-based techniques with which they were already familiar. Neither required radical adaptation for these special operational environments, such as might be necessary for zero-g operations. Unlike space teams, these experimenters did not experience any significant acceleration stresses during "launch" or return. The interior of the airborne laboratory was large enough to permit freedom of movement, with visual and verbal contact among the scientists as work periods permitted (Reference 8). Physical and psychological "isolation and confinement" were minimal, therefore, and no participants reported any problems attributable to these factors.

The flight-team scientists themselves had proposed the topics of study they were pursuing, selected the appropriate instruments, and developed the operational procedures to attain their objectives. As a result, maximum compatibility and acceptability to each user were reasonably assured. The flight teams, in short, represented a group of skilled and intelligent men, each of whom thoroughly understood what he was trying to do and was highly motivated to do the best possible job of it.

To a large extent each scientist also similarly understood the other onboard experiments and shared in the motivation for their success, since some of the data in their concurrent observations and flight-profile information were of mutual value. However, any problems or delays that developed within them could potentially affect the whole group's airborne time and flight profiles. Thus, these other experiments also represented constraints and conflicts if individual problems developed.

Inflight activities covered scientific, technical and managerial tasks related to the conduct of each individual experiment, and to the overall success and safety of the flight (see Figure 1). The scientific teams' tasks included:

a) Monitoring, maintaining, and "fine tuning" of their individual instruments. For example, in one of the experiments that used a scanning spectrometer, dark-count measurement calibration with a low brightness source, and recharging with "dry ice" between measurements, were performed each hour during the flight.

b) Recording of supplementary data, such as significant auroral events and correlates from other experiments, either in logs or on the instrumentation strip charts. Real-time readouts or "quick look" capabilities greatly facilitated monitoring of changing auroral conditions and instrument performance.

In addition to working with his own equipment, each scientist served at one time or another as an "aurora spotter". The spotters in the cockpit area would advise and consult with the other experimenters so that, on the basis of their visual sightings, their real-time evaluations of auroral conditions, and discussions with the management and flight team, they could decide how they might modify the existing flight plan to maximize the yield of scientific data. Flight profiles and the participants' real-time comments on sky conditions were also recorded on intercom voice tapes. The experimenters later reported they felt that some of the more important auroral data resulted, at least in part, from this real-time operational flexibility and from the presence of scientists to directly observe the visual phenomena, spot-check multiple instrument readouts, interact with other ongoing experiments and record relevant supplementary data.

The inflight activities of the NASA management-support team paralleled those of the scientists on a somewhat broader scale. In addition to the directly scientific support tasks already mentioned, the status of the vehicle systems, fuel supply, flight conditions, availability of alternate fields and their facilities and support personnel, all had to be monitored in order to permit optimum real-time planning and response to the scientists' requests to modify flight schedules. The scientists' views of these "real-world" constraints will be discussed later in relation to problems of leadership in planning and management of multi-disciplinary scientific missions.

Living and working conditions at the main ground station (see Table I-B) were moderately demanding. This was primarily because of operational factors attributable to the sub-Arctic winter environment, rather than the design or use of the facilities themselves. The Churchill Test Range is a permanent base with excellent resources and the limiting behavioral aspect of these resources was the site's remoteness (i.e., its physical distance from main-land sites), rather than any operational or social isolation (i.e., there were few limits on resupply or information exchange with the outside world). The snow, glare, wind, and temperatures constituted continuous hazards to both the men and their equipment; but advance planning and briefings minimized their operational impacts. No significant complaints about the sub-Arctic weather or living conditions were made by any team member in response to inquiries in the present study.

More actual mission time, by far, was spent on the ground than in the air. The ratio of ground time to flight time was planned to be approximately 9.4:1 (64 hours in 13 flights, during a 25-day period). The actual ratio proved to be almost twice as high, 17.5:1 (34.25 hours in nine flights, for the same period). This resulted from problems with the CV-990 systems and some of the experimental equipment. For example, one flight had to be aborted due to failure of cabin pressurization. The teams' reactions to such events are discussed later in relation to real-time management problems.

Ground time during the mission covered many activities. In addition to those planning and support functions indicated in Figure 1, the mission personnel engaged in off-duty activities covering everything from individual rest and eating to small-group socializing (such as holding "bull sessions" in each other's rooms) and keeping in touch with their organizations and families by mail and phone. Recreational facilities (such as movies, gymnasium, and books) were available and well used. The food was considered very good, both in variety and quality. Assignment of living quarters were based largely on work categories (to minimize noise disturbances due to different teams of base and support personnel with different schedules). Heat and hot water were plentiful. Overall, the inconveniences of the quarters and personal support facilities were considered minor and were not sources of complaints. To some extent, room-swapping to permit self-optimizing of roommates took place, and advance planning and management effectively provided for these interpersonal considerations.

The present data are not exhaustive and do not indicate any general within-mission changes in these interpersonal patterns or the group's reactions to the personnel support facilities. But, it is reasonable to anticipate that some negative changes would probably occur within these populations eventually - if mission durations were significantly extended, or if operational stresses (such as long stretches of bad weather or equipment failures ruining experimental plans) decreased the motivating rewards the men gained while living and working in these environments. For a mission stay of a little over three weeks duration, they succeeded in accommodating to each other, and to their surroundings, with no general difficulties.

To make the mission successful, each of the scientists and support team members had to be able to do many things under demanding circumstances. For example, they had to be able to adapt to the unfamiliar operational environments, cooperate in performing their own tasks, support each other where necessary, and resolve potentially conflicting requirements without compromising their individual and overall scientific objectives. However, the participants were not selected on the basis of any personal information which evaluated whether or not they would be likely to do all this. In effect, they "came" with their experiments. Their selection resulted from evaluations of the experiments they had proposed. Each experiment had been judged on its scientific quality, and its compatibility with the overall objectives of the Auroral program and the operational capabilities in the CV-990 aircraft. Except for professional backgrounds, supplied with these experiment proposals, no information on the participants, other than citizenship, clearance status, and clothing sizes, was sought until the mission was underway.

The scheduled participants periodically received written briefings on each other's experimental plans and the overall evolving program, details of the on-site working and living conditions, and tentative flight schedules. This information, plus group-planning meetings, also helped resolve personal uncertainties and facilitated the development of a degree of cooperation that could not be established within the original screening and selection processes.

Table II provides summary biographic and demographic profiles of the 24 individuals who made up the scientific teams (N = 15) and mission support teams (N = 9). These personal descriptors were selected because they are objective factors that can be readily identified in pre-mission inquiries without special test, and are also variables that prior investigations have indicated tend to relate to successful performance within small groups in similar remote operational environments (See, for example, Reference 5).

Despite the small sample populations, several interesting similarities and distinctions of potential interest to interpersonal compatibility are readily seen. In both groups all participants were married, mature, and relatively well educated. However, the scientist team was typically about ten years younger than the support team, and included a high proportion of PhD's (7 out of 15) while the support team contained none. The personal backgrounds of both groups were similar, except that a high proportion of the scientist team were foreign-born (5 out of 15) compared to none for

TABLE II

SUMMARY PROFILES OF AURORAL FLIGHT PERSONNEL

(TOTAL SAMPLE GROUP N = 24, JANUARY – FEBRUARY, 1968)

DESCRIPTOR	SCIENTIST & EXPERIMENT TEAMS (N = 15)		MANAGEMENT & FLIGHT CREWS (N = 9)	
	MEDIAN (* = MODE)	RANGE	MEDIAN (* = MODE)	RANGE
a) AGE: (YEARS)	33	22 – 49	43	33 – 54
b) EDUCATION	M. S.	H. S. (1) – PH. D. (7)	B. S.	H. S. (2) – M. S. (3)
c) SIZE OF HOMETOWN	TOWN: 5K – 50K	RURAL $<$5K (3) – CITY $>$500K (2)	CITY: 50K – 500K	TOWN: 5K – 50K (4) – CITY $>$500K (2)
d) LOCATION OF HOMETOWN	*USA: MIDWEST	USA (10)/FOREIGN (5)	*USA: NORTHEAST	ALL USA
e) CHILDHOOD MOBILITY: (FAMILY MOVES TO AGE 18)	3	0 – 10	3	0 – 8
f) NUMBER OF SIBLINGS	2	0 – 6	2	0 – 7
g) BIRTH ORDER	FIRSTBORN	FIRST (10)/LATER (5)	LATERBORN	FIRST (2)/LATER (7)
h) MARITAL STATUS	*MARRIED	ALL MARRIED	*MARRIED	ALL MARRIED
i) PRIOR ARCTIC EXPERIENCE	SOME	NONE (7) – EXTENSIVE (5)	NONE	NONE (7) – SOME (2)
j) OTHER FIELD RESEARCH EXPERIENCE	SOME	NONE (3) – EXTENSIVE (7)	EXTENSIVE	NONE (2) – EXTENSIVE (6)

the support team, and two-thirds of the scientists were first-born children while the proportion was approximately reversed in the support team. As for prior experience in field research or Arctic studies, both groups presented a mixed picture, with the support team being more heterogeneous than the scientists.

Table III provides a comparison of the average age and experience backgrounds of each group of U.S. astronauts at the time of their selection (Reference 12). Both of the scientist-astronaut groups selected to date have been approximately the same average age as the other astronauts and as the scientists in the present study. In addition, the educational level of the present scientist team tends to match that of the scientist-astronaut groups, while the pilot-astronauts' education more closely matches that of the auroral support teams. On this admittedly small number of dimensions, it would appear that the backgrounds of this study's scientist teams are reasonably similar to the astronaut-scientists, and that their behavioral characteristics under these mission conditions may offer some forecast of the probable characteristics of future space scientist teams.

3.3 Behavior and Performance Patterns

In these next sections, we will indicate in some detail how data on these teams behavior and performance were obtained and evaluated, and review the results. Our primary concern will not be to analyze the particular events and individuals sampled in this study exhaustively, but to relate the information obtained to possible future earth-based and space-based scientific missions.

The multivariate investigative measures used are briefly described in the next sections. From the multiple sources of data potentially available in a field study without special monitoring facilities or common test-tasks, a composite battery of measures was developed. The combined behavior-performance scores were subjected to a principal components factor analysis (Ref. 5 & 10) to reveal how the scores on the individual criteria related to one another and to the overall criterion set. Two principal factors emerged, reflecting differential behavior patterns among the scientist and non-scientist populations. Then, using the background profiles of the participants, estimated criterion scores were derived for each team member, within a multiple regression analysis (Refs. 5 & 10). The patterns of correlations of each of the personal descriptors with the composite behavior-performance scores defined by the two principal factors were also examined.

TABLE III

COMPARISON OF ASTRONAUT GROUPS

AT TIME OF SELECTION

GROUP	DATE	NUMBER SELECTED	BASIC REQUIREMENTS		GROUP PROFILES		
			PILOT	EDUCATION	AGE	COLLEGE YEARS	FLIGHT HRS.
1	APR. 59	7	REQ.	BS (ENGR) OR EQUIVALENT	34.5	4.3	3500
2	SEPT. 62	9	REQ.	BS (PHYSICAL, BIOLOGICAL OR ENGR SCIENCE)	32.5	4.6	2800
3	OCT. 63	14	REQ.	(SAME AS GROUP 2)	30.0	5.6	2315
4	JUNE 65	6	*OPT.	GRAD. WORK IN PHYSICAL BIO-LOGICAL OR ENGR. SCIENCE)	31.2	8.0	*
5	APR. 66	19	REQ.	(SAME AS GROUP 2)	32.8	5.8	2714
6	AUG. 67	11	*OPT.	(SAME AS GROUP 4)	33.0	8.3	*

*NOTE: PILOT EXPERIENCE NOT REQUIRED FOR SELECTION OF SCIENTIST-ASTRONAUTS (GROUPS 4 AND 6) (ADAPTED FROM REF. 12)

3.3.1 Multivariate Measures and Evaluation Methods

Since almost infinitely many variables may influence human behavior in complex "real-world" situations the questions of what to measure, and how, must often be answered pragmatically. The basic problem is how to balance the conflicting requirements of completeness (with greater complexity and effort) and simplicity (with possible loss of some descriptive and predictive capabilities).

In this study, different types of data were derived from the pre-mission, mission, and post-mission periods. The following analyses combine: (1) the pre-mission biographic profiles, described in the preceding sections, (2) direct observations and structured self-reports of within-mission behavior, and (3) post-mission management ratings of how well each man performed his duties, adapted to the operational conditions, and interacted with the other team members.

Other supplementary items ranged from inflight voice tapes of communications among the scientific team members to personality and mood assessment materials. Their contributions proved to be marginal because of methodological problems, such as the small and unequal sample sizes that resulted when many participants did not complete all parts of the forms after the mission. No systematic bias in the present conclusions could be identified from the omission of these secondary materials, either in terms of the profiles of the responding and non-responding populations or in the contents of the within-mission results.

Table IV shows the combined sets of behavior-performance variables and personal profile descriptors, and Appendix B shows the source materials from which they were derived. In the behavior-performance measures of Table IV-A, items 1-4 were derived from Form C in Appendix B. They were designed to obtain a variety of feedback from the mission managers, by having them rate each individual on positive and negative aspects of his mission work performance, personal adaptation, and interpersonal effectiveness with the other team members. Items 5 & 6 (see Form D) represent each team member's nominations for those individuals he would personally like to have along on a similar expedition in the future, regardless of job category. Nominations by the scientists and non-scientists are listed separately to permit identification of preference patterns, such as whether both groups tended to select the same individuals or, if not, how they weighed personal backgrounds or behavioral characteristics in selecting possible teammates.

TABLE IV

GROUP BEHAVIOR – PERFORMANCE PATTERNS AND PERSONAL DESCRIPTORS

A. BEHAVIOR – PERFORMANCE MEASURES			B. PERSONAL DESCRIPTOR MEASURES		
CRITERION VARIABLES	PRINCIPAL FACTORS I. (LOADINGS)	PRINCIPAL FACTORS II. (LOADINGS)	PREDICTOR VARIABLES	INDIVIDUAL CORRELATIONS WITH PRINCIPAL FACTOR SCORES I.	INDIVIDUAL CORRELATIONS WITH PRINCIPAL FACTOR SCORES II.
1. WORK RATING (BY MGT)	.353	.225	a) AGE	.571	.052
2. COOPERATIVENESS (BY MGT)	.400	.157	b) EDUCATION	–.261	.488
3. ADJUSTMENT (BY MGT)	.330	.418	d) HOMETOWN SIZE	.245	.104
4. NEGATIVE SYMPTOMS (BY MGT)	–.386	–.218	e) CHILDHOOD MOBILITY	–.146	–.009
5. NOMINATIONS (BY SCI)	–.081	.455	f) #SIBLINGS	–.242	–.248
6. NOMINATIONS (BY MGT/SUPP)	.422	.039	g) BIRTH ORDER	.081	–.425
7. MEALTIME (WITH SCI)	–.330	.454	i) ARCTIC EXPERIENCE	.011	.517
8. MEALTIME (WITH MGT/SUPP)	.384	–.377	j) FIELD EXPERIENCE	.605	.538
9. #ELIGIBLE FLIGHTS MISSED	–.128	.382	MULTIPLE CORRELATIONS WITH PRINCIPAL FACTOR SCORES	.806	.889
% OF TOTAL VARIANCE	42.2	21.9			
CUMULATIVE % VARIANCE	42.2	64.1			

+NOTE: DESCRIPTORS FOR HOMETOWN LOCATIONS AND MARITAL STATUS WERE NOT INCLUDED IN PRESENT STATISTICAL ANALYSES. SEE TABLE II (ITEMS c & h)

The remaining criterion variables were derived from direct observation, rather than by questioning the participants. Items 7 and 8 sample the socialization patterns at meal-times over a two-week observation period. Several factors influence how well unobtrusive observation of meal-time association and seating patterns can partially assess gregariousness or within-group isolation patterns. They include the facts that everyone was not usually present at the same time, and that group sizes were limited by table size, although seating patterns could and did change during a given meal. The last variable, Item 9, brings in the possibility that any individual might fail to participate in some fraction of the scheduled flights; and that such absences could reflect operational, personal, or interpersonal problems.

Multivariate evaluations are used to compensate for the fact that the important underlying factors in a given situation may not be directly measurable. In fact, these factors may not even be known a priori. Pooling data from a battery of measures sampling aspects of interest, we can examine the distribution of scores within the multidimensional space of these measures. If the data reflect significant features of the composite situation, scores will tend to cluster or form patterns that can be meaningfully related to similarities and differences in the people and conditions from which they were obtained. We can consider any dimension or vector through the multidimensional space of the individual measures as a possible "factor", and readily analyze the scores to obtain their projections, or "loadings", on any given set of "factors". If a few "factors" can be found to account for a relatively large proportion of the observed variance in the score distributions, they may lead to a simpler model of the patterns in the data. "Principal components analysis" (Ref. 10) is a technique for constructing a sequence of "factors" such that each successively maximizes the proportion of remaining score variance for which its loadings can account. In order for the results to be useful, we must be able to interpret the "principal factors" as real factors in the situation under study.

3.3.2 Results and Evaluations

The score distributions were analyzed to determine their loadings on a series of linear axes, or principal component factors, projected through these distributions. (Ref. 10).

Six such factors cumulatively accounted for approximately 95 percent of the total variance. Rotation of this factor array to simplify the loading patterns of the individual measures was tested, but the resulting patterns tended to reflect the sources and methods of measurement from which they were derived (ratings, nominations, observations). The original unrotated factors therefore appear to present a more meaningful composite performance picture.

In particular, the first two principal factors seemed to provide a useful and interesting summary of the "true score" components within this set of rating-nomination-observation measures. These two factors accounted for over 64% of the total score variance, and their loadings on the component criterion variables are shown in the columns of Table IV-A.

The first factor seems to represent good mission performance and adjustment from a management-support team orientation, while the second may be interpreted as representing the scientist team orientation. These two factors, accounting for 42.2% and 21.9% of the total variance respectively, present some interesting similarities and differences. Overall, the patterns they reveal tend to support the reports by other investigators that "compatibility, or fitting in with the group, is at least as important as job performance in the eyes of both leaders and peers" (Ref. 3).

If we examine the patterns of their loadings on the individual criterion measures, the first four criteria reflect what we would expect--both factors show loadings that are positive and approximately equal for the desirable aspects of work, cooperativeness and adjustment and negative loadings for undesirable behavioral symptoms, as measured by management ratings. However, their loadings on the last five measures tend to present contrasting patterns.

Factor I weights positively toward mealtime socialization with the management team, and with their nominations for participants in similar future missions. But it loads negatively and near-zero with regard to the same measures when related to the scientist team. As might be expected from management's viewpoint, it also weights negatively toward a team member's missing any flights for which he was eligible.

Factor II shows a converse pattern. It weights positively for scientist team associations and nominations, and near-zero for management-support team nominations.

Surprisingly, this second scientist-oriented factor did not load negatively on the number of flights missed. A possible explanation for this may be found in the relatively independent nature of the individual experiments on these flights. The result was that the scientists apparently did not tend to consider a peer's missing a flight to be as significant in their attitudes toward him as did the management team, who had the responsibility for maximizing mission participation.

Evaluations were also made of how the personal profile data on the 22 mission members for whom complete biographical and behavior-performance data were available related to the battery of criterion measures.

Their criterion scores and personal profiles were used in a multiple regression analysis (References 5 & 10) of the predictability of the behavior-performance measures from these biographical descriptors. Linear regression equations were derived, in which weightings were determined for each of the eight biographical descriptors, and these were used to calculate "predicted" scores for the two principal criterion factors. The correlations of the individual personal descriptors and the overall set of multiple descriptors with these scores are shown in Table IV-B.

The correlation of the management-oriented measures (Factor I) with a linear combination of the eight biographical descriptors was $r=.81$ (statistically significant at the $p<.05$ level of confidence). The single most important individual predictor ($r=.60$) was prior experience on similar expeditions. Age also correlated positively ($r=.57$), but in the regression equation this effect was apparently submerged in the related experience variable (i.e., the older men also tended to have field research experience). Interestingly, prior Arctic experience did not correlate with this criterion score ($r=.01$), and in fact this predictor shows a negative weight, although not a statistically significant one, in the regression equation. This may reflect a "know-it-all" effect. That is, some of the scientists had considerably more Arctic experience than the managers themselves, and this led to arguments over management decisions.

The scientist-oriented measures (Factor II) correlated $r=.89$ ($p<.01$) with the linear combination of the eight biographical descriptors. The best individual predictors were education ($r=.49$) and both prior Arctic experience ($r=.52$) and prior field research experience ($r=.54$). Thus the scientists showed a different pattern from the management team in their evaluation of Arctic experience (which usually meant greater familiarity with Auroral phenomena as well) in addition to other field research experience. The stronger positive relation to the education predictor seems straightforward, although it may be magnified by a general preference on the part of the scientists for other scientists (rather than management-support team members). A similar effect may be present in the birth-order predictor (r= -.42, i.e. first-borns tended to rate higher on the scientist-oriented measures) since the scientists were predominately first-born and the management-support team predominately later-born.

In summary, these analyses indicate that behavior-performance evaluations derived from combined rating-nomination-observation measures may be reasonably well predicted from pre-mission biographical data. However, the interrelations among these predictor and criterion measures are not invariant. Such variables as an individual's age, education, and specific forms of experience do not show simple positive relations to good mission adjustment and performance, and tend to differ for the management and scientist teams. In general, those mission members with similar personal backgrounds and mission roles are more likely to associate during off-duty periods, and also tend to nominate each other for similar future missions.

3.4 Leadership in Multi-Disciplinary Scientific Missions

Attitudes and personality characteristics of scientists may lead to leadership and management problems, since they are typically intelligent and independent individuals who tend to question authority and plans of action, especially in their areas of scientific interest.

In a scientific field operation such as the Auroral expedition, which brings together individuals from many organizations for a limited time, clear-cut and traditional lines of authority do not exist. Many goals must be combined and differences reconciled. But, the managers of such an operation have very limited power to control member behavior through customary boss-employee sanctions and more complex leadership patterns must evolve. This point was emphasized by the mission managers in a pre-mission interview:

"...An organization with so many aspects as this one depends on the cooperation of a lot of people over whom you do not have jurisdiction. People who don't work for me -- I have to get their cooperation. And this goes for the scientists, the ground crew, the contract people, people in the other divisions around here. It's an operation which no matter what the organizational lines are, it's almost meaningless. The crux of getting it going is your individual's cooperation, regardless of what the organizational lines are. That, I think, probably is the most important thing."

Thus, the success of such an operation depends heavily on the common interests and goals of the participants, and the personal leadership qualities of those in charge -- a capacity to command respect, and ability to convince and persuade. Personal authority must substitute for institutional authority. "What you really need...is a scientist who really is like a Dr. Einstein. Who says, 'This is what we're going to do', and everybody bows down to him and says, 'All right, this is what we're going to do'."

Studies of leadership qualities and techniques in small groups in emergencies or extreme conditions (Reference 9) have identified six ways in which a leader can reinforce his position in such field situations:

1) demonstrating competence and expertness, especially in troubled situations;

2) readiness to take risks and share discomfort;

3) willingness to make decisions and take action;

4) readiness to act outside authority;

5) willingness to care for the men;

6) willingness to require discipline.

Several of these points were brought out by one of the managers when asked what he felt were the special qualities needed by the people coordinating such expeditions:

> "...An ability to make decisions is important. A guy who's wishy-washy just won't get any place. You get a lot of these people coming to you for an answer, whereas they know the answer better than you do. But they need Daddy's pat on the head before they're satisfied...So the various factors that go into leadership normally would apply here. And one of them is the ability to make a decision, even if you don't know what you're talking about."

This view should be tempered by a realization that the complexity of many of the science-related management problems make it unlikely that a spur-of-the-moment decision, no matter how forcefully stated, will always be accepted as satisfactory. Furthermore, Navy studies on technical teams in Antarctic stations indicate that, while decisiveness maybe a necessary condition for effective leadership in such operations, it is not sufficient.

> "There is a tendency to equate self-confidence, assertiveness, and achievement motivation with with leadership...Data from several small station groups indicate that the more effective leaders (as judged by the station supervisors and the men themselves) exhibit more emotional control, flexibility, and greater interest and concern for the problems of individual station members than do the less effective leaders. On the other hand, the more and less effective leaders tend to be characterized equally by greater self-confidence and achievement orientation than are the non-leaders." (Reference 9.)

In another management interview, examples of how leadership problems were directly affected by the scientists' attitudes within this mission, were placed in operational perspective:

> "...By and large, they do not have much understanding of the operational problems. There are some exceptions, but in general they come up to you with their scientific requirements, and that's the purpose of the mission, and they can't understand why you can't go along with an eight-hour flight even though the fuel tanks will only hold seven hours worth of fuel" ...(It is not so much a lack of curiosity about the operational aspects of the mission)..."really, a lack of interest about the operational problems.

> Oh, they want to know what we're going to do, and little by little they learn the limitations -- you just can't fly more than seven hours; well maybe if the wind goes right, we'll get seven-and-a-half. Well, they come to accept these things. But not with any friendliness---Rather than be happy that we can provide seven hours, they're unhappy that we can't provide seven-and-a-half...They look upon operation as a limitation and not so much as a service...Now this isn't completely fair to them. This is the case during the operation. After we get back, I've had some wonderful letters that 'I appreciate how smoothly you've run things' and,...after they're over the stress of the expedition, they relax, and they're very appreciative of all we've done for them in the past few weeks."

On the maintenance of scientific apparatus in these demanding field conditions:

> "...This is something that we had to learn. We went down with insufficient support crew. We never thought that, after spending eight hours in flight and briefings and so forth -- maybe even ten hours if there was a long flight, between the briefings and everything we spend maybe a ten-hour day -- we never thought that they'd come back after dinner and work another five hours to straighten out some faulty power supply or something. But they do. They work like beavers. They really work hard. Every place else that we've been where the weather has been good, they were working eighteen hours a day or more on the airplane. We had to schedule some aircraft people around the clock. Because any time of day or night these guys would show up and keep on working--adjusting and changing, fooling around. There's no stopping them!"

3.5 Scientist Motivations and Role Conflicts

When we ask questions about what scientists do under given circumstances, we also implicitly ask about what they do not do. In a large expedition some behaviors that would be appropriate in their own laboratories might have to be delegated to others or be coordinated with a group. Problems involved in the integration of multi-disciplinary objectives can require compromises that each scientist must accept, or at least cooperate with, if the combined mission is to achieve all of its goals.

Each scientist is motivated to produce the best possible scientific results within his own experiment. This is a reasonable assumption. But the implications of this motivation can potentially conflict with the requirements imposed upon him by his role as an experimenter in a multi-purpose mission. For example, a scientist's abilities to identify targets-of-opportunity may not stop after planning decisions have been made, but his abilities to respond to them may change drastically. When his scientific habit patterns must be changed, or his autonomy relinquished, the potential for dissatisfaction and role conflicts increases. As these Auroral flights developed it became quite clear that just such a situation existed.

Extensive pre-mission coordination and briefing materials had been given to the flight teams, which carefully described the extent and reasons for the limitations on the management team's abilities to modify plans in real-time. This was done in order to optimize the preflight planning and prepare the scientists to accept the conditions they would experience during the mission. These efforts were not totally successful since considerable dissatisfaction with parts of the flight plans was expressed during the mission phase.

Figure 1-B indicates the within-mission concerns of both the management and experiment teams, and it can be seen that considerable overlap exists between them. Problems developed which had to be reconciled according to the best available options. For example, one of the original flight experiments (Fabry-Perot interferometer) had to be shifted to a ground station after problems with its operation in the aircraft threatened to delay the other experiments. Planned flights in coordination with high-altitude rockets also proved to be more difficult than had been anticipated. This involved a precision of flight path that was time-consuming,and potentially hazardous if the rocket aim was not perfect. It was also not considered equal in interest to "Aurora-chasing" by most of the experimenter team. These points were discussed by the managers and the scientists, and attempts were made to incorporate alternative flight proposals offered by the scientist team as a group.

The experimenters tended to persist in the planning functions to which they had contributed in the pre-mission phases, and considerable within-mission re-evaluation and bargaining was attempted. However, the scientists were not as attuned to the multiple constraints as the NASA management team, and they often suggested operational modifications which could not be granted for reasons they considered extra-scientific (See Appendix C). Since the experimenters proposed things which they considered scientifically valid, and reasoned that the entire purpose of the expedition was scientific, it took considerable skill and leadership to balance all these factors and still maintain the respect and cooperation of the participants (See previous section).

These points are well summarized in the Circular Letter to the experimenters (See Appendix C) which the Airborne Science Office distributed after the first series of flights had been completed. Post-mission discussions with the participants indicated that, typically, after the stress of the missions was past, the apparent need to compete for "optimized" schedules subsided and the scientists commented favorably about the devotion and skill demonstrated by the management-support team under admittedly difficult field operation conditions. Thus, these were apparently short-term situation-specific behaviors and did not interfere with full information exchange and cooperation in the post-mission phases.

4.0 SUMMARY AND COMMENTS

This study was exploratory and necessarily limited in scope. A more comprehensive investigation of how the many variables that affect human performance in groups of this size combine and interact in non-laboratory operational situations would have required much more time, resources, and investigative personnel than were available.

Within these limitations, however, such operational investigations yield additional insights into the nature of the problems of planning the activities and supporting the personnel who participate in multi-disciplinary scientific missions. The results, although less statistically "tidy" than might be obtained in controlled simulations, embody "real-world" behavioral factors which are difficult, if not impossible, to adequately simulate - i.e., real rewards, stresses, motivations, conflicts, and operational reactions.

These CV-990 auroral flights combine many elements that are analogous to those in shuttle sortie missions. Accordingly, the selection, planning and coordination procedures now developing through the use of NASA's Airborne Laboratory represent the best available models of the effectiveness with which such future space efforts are likely to accomplish their scientific objectives.

Behavior and performance factors have been emphasized in this report, rather than problems specific to the sub-Arctic station or to the engineering and design of the flight vehicles or experiment instruments. Well established techniques exist for identifying, attacking and resolving problems in those areas. Problems of leadership and mission management are less well defined, less well documented, and therefore more likely to persist as sources of potential scientific failure in future missions.

The present data indicate:

a) Direct observations and evaluations of situational behavior patterns among the participants in scientific missions can reveal stresses, conflicts, and effects of management techniques that may not be fully anticipated or designed into formal test instruments.

b) Judgments by the participants of how well scientific team members function tend to reflect large socio-psychological components, especially when the scientific products themselves cannot be readily evaluated during the mission.

Individuals with similar backgrounds and mission roles are more likely to associate during off-duty periods, and to nominate each other for similar future missions.

c) Sources of dissatisfaction tend to be those program elements the participants feel are both important and amenable to change (e.g., scheduling), rather than those which are physically stressful, but not changeable (e.g., sub-Arctic winter weather). When equipment design and selection have been largely determined by the participants, they do not tend to be perceived as significant within-mission problems to those users.

d) Behavior in scientific missions may reflect conflicts in the participants' motivations and mission roles.

Motivational conflicts may be attributed to the degree to which different experiments and program goals constrain one another and require compromise of the individual experimenter's possible results.

Role conflicts may reflect a persistence in real-time data evaluation and planning functions that an individual investigator carries over from his ground-based laboratory work patterns. They can also be partly attributed to the scientist's reservations about delegating such decisions to a management team whose objectives include elements he may not consider equally important and whose scientific background is less expert than his own. Effective team leadership and real-time planning must attempt to balance all these factors in order to maintain optimum feedback and team cooperation.

5.0 ACKNOWLEDGEMENT

The author wishes to thank Dr. N. Zill for his cooperation and programming of the data analyses.

B. A. Gropper

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Attachments
  Appendices A-C
  References

APPENDIX A

The following papers are a sample of the scientific results obtained from these missions. These papers were presented at a "Symposium on Results of the 1968 Airborne Auroral Expedition" in the 50th Annual Meeting of the American Geophysical Union, Washington, D. C., April 13, 1969

(STA88)

Louis C. Haughney
Michel Bader
NASA Ames Research Center, Moffett Field, Calif.

The NASA 1968 Airborne Aurora and Airglow Expedition. NASA organized and managed an expedition to the arctic region to observe auroras and airglow from its airborne laboratory, a modified Convair 990 four-engine jet aircraft. Based primarily at the Churchill Research Range, Manitoba, the aircraft made nineteen flights at altitudes up to 40,000 feet over northern Canada and Alaska as follows: within and across the auroral oval; Churchill to Alaska in constant local time along a parallel of geomagnetic latitude; return in accelerated local time; north-south survey from Churchill to the geomagnetic north pole along a geomagnetic meridian; and flights timed for coordination with the OGO-IV satellite both when overhead and when at the aircraft's magnetic conjugate point. The fourteen participating experiments from universities, industry, and government agencies included spectrophotometers, photometers, an all-sky camera, a riometer, and a magnetometer. The unique advantages of the airborne observations were first, the altitude, which gave freedom from cloud cover and access to the infrared; and second, the mobility, which permitted covering about 8° of latitude per hour or, alternatively, following auroral phenomena in constant local time. During the airborne expedition, January-March, 1968, the auroral activity was generally quiet. The average magnetic index Kp was only 2^- during the flight times.

(STA89)

S.-I. Akasofu
Geophysical Institute
College, Alaska

Auroral Observations by the Constant Local Time Flight. The concept of the auroral substorm was tested and confirmed by observing auroras from a jet plane flying twice westward from Churchill, Canada to Fairbanks, Alaska. For each flight the plane remained approximately in the late evening and midnight sectors for more than 5 hr. Two auroral and polar magnetic substorms were observed during the first flight and one during the second flight. Both auroral and magnetic conditions before and after the substorms were quiet.

(STA90)

E.J.Llewellyn
H.C.Wood
A.Vallance Jones*

Physics Dept.
Univ. of Saskatchewan
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(* Now at Radio & Electrical Engineering Div. National Research Council, Ottawa, Ont., Canada).

The auroral emission of the infrared atmospheric system of oxygen.

The intensity of the auroral emission of the infrared atmospheric oxygen at 1.27μ has been measured with a two channel interference filter photometer flown on the NASA Airborne Auroral Expedition. The pre-auroral measurements indicated a latitude independent nightglow intensity of 100kR and the auroral measurements, which were made under varying levels of auroral activity, have been compared against this nightglow intensity. The observations indicate that the infrared oxygen emission is only significantly enhanced, approximately 200kR, in intense aurora when the oxygen green line intensity is greater than 20kR. The apparent correlation of the two emissions has permitted a determination of the lifetime of the excited state as approximately 100 seconds. It is shown that the difference between the auroral lifetime and that reported for the twilight emission may be explained in terms of quenching by atomic oxygen, if the excitation mechanism is through low energy electrons.

(STA91)
K. A. Dick
H. M. Crosswhite
G. G. Sivjee
Johns Hopkins Univ., Baltimore, Md.

Airborne Measurements of OI, O_2 and OH Nightglow Intensities. The 1968 Airborne Auroral Expedition made several flights outside the auroral zone. During these flights, nightglow emissions were studied using a one-meter Ebert spectrophotometer which scanned the region $n\lambda$ = 12,600 Å to 14,000 Å with order sorting filters designed to pass either second or fourth order features. The second order range included OI 6300, 6364 Å lines and the OH Meinel bands (6,1) and (7,2). The fourth order region contained bands of the O_2 Herzberg system. Spectral scans were summed in a Fabri-Tek instrument computer for 16 minutes (64 scans) with one set of filters, the memory dumped onto strip chart recorders, and the procedure repeated for the alternate order. Intensities of the features recorded are presented and plotted against geographic latitude and local time. The intensity of OI 5577 Å is also presented as obtained from a filter wheel photometer bore-sighted with the spectrophotometer. This photometer also monitored N_2^+ 3914 Å, enabling detection of auroral contribution to the nightglow spectrum.

(STA92)
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(*NASA Pre-doctoral Trainee)

Spectrophotometry of Aurora and Airglow from an Aircraft. A 1/2 meter Ebert-Fastie spectrometer was one of several instruments aboard NASA 711 during the late winter, early spring of 1968. From four flights at low and middle latitudes, the Herzberg I band system of O_2 in the near UV and the [OI] 5577 Å line were mapped from 12° N (invarient latitude) to the auroral oval. The two emissions co-varied outside the auroral oval. Several flights into the polar cap during magnetically quiet periods showed that the Herzberg I system was brighter than auroral emissions in the 3000 Å to 4000 Å spectral region. Very high time resolution spectra of the aurora in the near UV were used to study the relative photon emission rates of the N_2 (2 P) and N_2 (VK) bands. On several occasions the aircraft flew along the path of the OGO-D satellite to attempt coordinated experiments. The results from one coordination are used to map the spectrum of an aurora from 1200 Å to 4100 Å.

(STA93)
T. D. Parkinson
E. C. Zipf
T. M. Donahue
The Univ. of Pittsburgh, Pittsburgh, Pa.

Phase and Amplitude Studies of the λ3914 and λ5577 Emission in Pulsating Auroras. A dual photometer continuously recorded the intensities of the λ3914 N_2^+ first negative emission and the λ5577 oxygen green line. Data was taken during the 1968 NASA Airborne Auroral Expedition. Analysis by numerical integration of the continuity equation for the $O(^1S)$ species, using the λ3914 as a source function, shows the phase lag expected for the .75 sec lifetime of the $O(^1S)$ state, but the slightly reduced amplitude at pulsation peaks is significant. This data is entirely consistent with a low altitude dissociative excitation (of O_2) source, which contributes about 90 per cent, and a high altitude dissociative recombination (of O_2^+) source which contributes about 10 per cent to the total green line intensity.

(STA94)
G. J. Romick
Geophysical Inst., Univ. of Alaska, College, Alaska

Relative Intensity Measurements of Auroral N_2^+, N^+ and OI Emissions. During the 1968 NASA Airborne Auroral Expedition, the Geophysical Institute operated a multiwavelength scanning photometer on board the NASA Convair 990 aircraft. Observations of the 4278 (N_2^+), 5000 (N^+) and 5577 [OI] auroral emissions were made under different auroral conditions. Many different types of auroral forms were scanned in zenith angle as the aircraft flew under them. This information can be used to investigate the latitudinal variations of the various emissions within the individual auroral forms. Of the data on discrete auroral arcs of I < 10 kR analysed so far, no appreciable differences exist between the N_2^+, N^+ and OI latitudinal profiles. However, the ratio of N_2^+/N^+ changes with intensity. Interpretation of these effects with regard to the relative composition of the neutral atmosphere and the pertinent excitation mechanisms will be discussed.

(STA95)
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D. P. Sipler
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Interferometric Study of Auroral OI λ5577 and λ6300 Line Shapes. A pressure tuned, photoelectric recording Fabry-Perot interferometer has been used to observe the shapes of the λ5577 and λ6300 OI auroral lines while aboard the NASA Convair 990 and from the ground at Fort Churchill. Excited atom temperatures have been determined from eighty-five λ5577 and thirty λ6300 line profiles analyzed on the basis of a gaussian emission line convolved with the expected instrumental function. Temperatures range from 120°K to 900°K for the green line with the bulk clustered around 400°K. For the red line the range is 800°K to 1600°K with the majority close to 1000°K. On one night the red line has been followed from twilight through a period of high activity. Temperatures fell from an early evening value close to 1100°K to a stable level near 800°K and rose again above 1000°K in the post break-up phase of the aurora. On several occasions doppler shifts in the λ5577 lines have been noted. This effect is attributed to bulk gas motions in the emitting layer with wind velocities of the order of 100 m/sec indicated. In some cases there appears to be a correlation between visual motion of auroral forms and wind direction.

(STA96)
S-I. Akasofu
Geophysical Institute
College, Alaska
R.H. Eather
J.N. Bradbury
Lockheed Palo Alto Research Lab.
Palo Alto, Calif.

The Absence of the Hydrogen Emission (Hβ) in the Westward Traveling Surge. It is shown that a westward traveling surge observed on March 3, 1968, was associated with an electron flux of order $4 \times 10^9/cm^2$ sec, while the Hβ emission was absent (<2R). It is suggested that the electron flux constitutes an upward (field-aligned) electric current from the surge, which is the western end of the auroral electrojet.

(STA97)
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Lockheed Research Lab.
Palo Alto, California

Short-Period Auroral Pulsations in λ6300 OI. λ6300 OI pulsations with quasi-periods of 2 to ~ 20 seconds have been observed in pulsating auroras. The percentage modulation was only 0.03 - 0.9%, compared to modulations of up to 60% in λ5577 OI and λ4278 N_2^+. Quenching rates are derived, and these show that shorter-period pulsations occur lower in the atmosphere and so are associated with more energetic electrons. Pulsation heights can be deduced only if the quenching coefficients are known.

(STA98)
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E. G. Joki
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Palo Alto, California

Riometer Measurements During the NASA 1968 Auroral Expedition. A multifrequency riometer system was flown on the NASA 711 jet aircraft during the 1968 auroral expedition. A total of seven absorption events were observed with durations ranging from a few minutes to two hours. The events were generally associated with auroral breakup as indicated by photometric measurements. A discussion of the results and problems encountered in operating an aircraft-based riometer system is presented.

(STA99)
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Results of an Airborne Geomagnetic Survey above 58°N Latitude. The 1968 Airborne Auroral Expedition included a free proton precession magnetometer and digital recording system having an absolute accuracy of ±1 gamma. Scalar profiles of the geomagnetic field were made along some 20,000 miles of flight path above latitude 58°N and in the vicinity of the geomagnetic North Pole. The experimental data has been compared to values calculated using harmonic analysis coefficient sets from two compilations. Preliminary analysis indicates that the GSFC (12/66) coefficients provide closer fit to the experimental data than those provided by the new International Geomagnetic Reference Field. A new method for accurately removing the magnetic field contribution of the aircraft from the experimental data is described in detail.

To facilitate the dissemination of information related to past programs and their scientific findings, the Airborne Science Office maintains a list of relevant publications (Reference 11). However, the formal ties between the program management and each group of participating scientists do not normally continue long beyond the missions themselves. Therefore, its accuracy and coverage of later publications depend to a large degree on informal continuation of the rapport and leadership qualities established during the mission phases.

The cover letter for the list of papers from previous programs, included in the briefing materials supplied to the participants in these flights, illustrates these points. It said in part, "If this compilation spurs you into working up and publishing any dust-gathering CV-990 results, we will send you a free snapshot of the aircraft and a hero medal. More important, we will add **your** name to the roster of those scientists whose work truly justifies the time, effort, and money spent by NASA in support of their programs".

APPENDIX B

Structured personal questionnaires, logs and management evaluation forms provided the primary sources of data within this study. These test batteries were designed to elicit the desired breadth of behavioral information from the participants in brief and largely self-administered formats based upon materials that had been used in previous similar investigations (Refs. 2 and 5).

The data for the statistical analyses and behavioral evaluations were largely derived from the following sources:

A. Pre-Mission Biographic and Demographic Profile -

(Answered individually by each team member)

BACKGROUND INFORMATION

1. Name, Institution, Title:

2. Age (Date of Birth):

   Birthplace and Hometown (if different):

3. Marital Status (incl. children):

4. Previous Experience and Education:

   a. Degrees, Institution, subject area:

   b. Previous Arctic experience:

   c. Other field-research experience:

5. Number of siblings:

   Were you the 1st, 2nd, 3rd ... child?

6. Up to the time when you were 18 years old, roughly how many times did your family move its residence?

B. Interview by Behavioral Investigator -

(Summary items recorded on all participants in the earliest practicable stages of the mission).

PERSONAL INTERVIEW

OUTLINE PRE-EXPEDITION

1. Name:
2. Brief description of experiment or duties:
3. Importance of work, to self, and to field:
4. What are you looking forward to most about the expedition?
5. What are you most concerned or apprehensive about on the expedition?
6. What people on the expedition did you know well before?
7. Any problems so far with equipment, logistics, or management (reaction to organization, rules conditions)?
8. Personality Impressions:

C. Post-Mission Management Ratings -

(Ratings obtained from both NASA Mission Managers on all other participants)

Name of person being evaluated ____________________

Rater ____________________

RATING SHEET

If you feel you have not observed the person enough to answer any of the following questions, mark "N.I." for no information.

1. How well has he carried out his responsibilities and performed his own duties?

Inadequately : Adequately : Well : Very Well : Exceptionally

2. He has cooperated with the other members of the expedition:

Defiantly : Grudgingly : Indifferently : Willingly : Enthusiastically

3. His overall adjustment to life on the expedition could be described best as:

Rough : A struggle, but a successful one : Slightly Choppy : Smooth : Excellent

4. Has this person exhibited the characteristics listed below? Mark "N" for no sign, "√" for some degree, and "√√" for substantial indication of the following feelings and behaviors.

Tension, nervousness ____
Irritability, faultfinding ____
Depression ____
Worry, anxiety ____
Preoccupation, absent-mindedness ____
Lack of interest, drive ____
Fatigue ____
Rule breaking ____
Repeated accidents ____
Decreased personal cleanliness ____
Frequent complaints ____
Increased drinking ____
Increased smoking ____
Social withdrawal ____

D. <u>Post-Mission Peer Nominations and Self-Ratings</u> -

(Answered individually by each team member)

Name:

1. On the basis of your experiences during this session of the expedition, who, from the members of this session, would you like to have with you on another similar expedition? List, in order of preference, the five people you would most prefer to have along. Don't be concerned about representing all jobs or positions in your list, just pick the five you would personally most like to have along.

   1. (most preferred)
   2.
   3.
   4.
   5.

2. How well do you think you yourself performed on the expedition?

:	:	:	:	:
Poorly	Not too well	All right	Well	Very well

3. If you had your choice, would you go on another similar expedition?

:	:	:	:	:
Would rather not go	Would go but with major reservations	Would go with some reservations	Would go	Would go enthusiastically

E. Post-Mission Scientist Attitudes -

(Answered only by members of scientist teams)

Name:

1. How much worthwhile data did you collect on this session?

:	:	:	:	:
A great deal less than expected	Somewhat less than expected	About what I expected	Somewhat more than expected	A great deal more than expected

2. Do you feel that you derived any scientific insights about auroral phenomena from direct participation in the expedition (as opposed to getting your data indirectly)? Describe briefly, if possible.

3. Was the presence of the other experimenters and their apparatus helpful or distracting?

4. What unexpected phenomena occurred? Did you have to make adjustments in your equipment or plans because of such phenomena?

5. Would you make major changes in equipment for another such session, given the opportunity and means? What sort?

6. In what ways would you like to see the organization and management of the expedition changed?

F. Daily Personal Log -

(Answered individually by each team member. Supplied bound in a pocket-sized log, with a separate page for each mission-day.)

Date: Time: Place:

1. Below is a list of words describing different kinds of moods and feelings. Indicate how you feel TODAY by placing a dash, check or two checks next to each word.

– = NOT AT ALL ✓ = SOMEWHAT OR SLIGHTLY ✓✓ = VERY MUCH OR GENERALLY

Cheerful	Relaxed	Pounding heart
Feeling blue	Irritated	Nausea
Uneasiness	Enthusiastic	Fatigue
Energetic	Jittery	Difficulty falling asleep
Angry	Headaches	Waking up at night
Sluggish	Upset stomach	Oversleeping
Bad dreams	Pain (where?)	Distracted (by what?)
Feeling lonely		

2. Personal observations (phenomena observed, ideas, data collected):

3. My major complaints today were:

4. My major sources of satisfaction today were:

(Use back of page for further comments)

G. Codings of Personal Descriptors -
(Coded by Behavioral Investigator - See Table II)

Item	Codings
a) Age (Years)	1 - n
b) Education (Highest Grade Completed)	1= 9th Grade 2= 10th Grade 3= 11th Grade 4= H.S. Graduate 5= 1-2 years College 6= 3-4 years College 7= Bachelor's Degree 8= Degree + Graduate Work 9= Master's Degree 10= Ph.D. or M.D. Degree
c) Size of Home Town	1= Rural 2= Village: $<$ 5K 3= Town: 5K - 50K 4= City: 50K - 500K 5= City: $>$ 500K
d) Location of Home Town	A= Me., N.H., Vt., R.I., Conn., Mass. B= N.Y., Pa., N.J., Del., Md., D.C. C= Va., N.C., S.C., Fla., Ga., Ala., Miss., La. D= W.Va., Ky., Tenn., Ark., Mo. E= Ohio., Mich., Ind., Ill., Wisc. F= Iowa, Minn., N.D., S.D., Nebr., Kans. G= Tex., Okla., N.Mex., Ariz. H= Colo., Ida., Mont., Nev., Utah, Wyo. I= Calif., Ore., Wash., Alaska, Hawaii J= Other - Foreign
e) Childhood Mobility (Number of Family Moves to Age 18)	0 - n
f) Number of Siblings	0 - n
g) Birth Order	1= Firstborn 2= Laterborn
h) Marital Status	0= Single 1= Married
i) Prior Arctic Experience	0= None 1= Some 2= Extensive
j) Other Field Research Experience	0= None 1= Some 2= Extensive

APPENDIX C

NASA - AMES RESEARCH CENTER
Moffett Field, California

1968 AIRBORNE AURORAL EXPEDITION

CIRCULAR LETTER TO EXPERIMENTERS

14 February 1968

It has come to my attention that a number of the experimenters feel that a greater number of flights and more attention to individual experimenters' flight pattern requirements should have been possible during our first three weeks at Fort Churchill. Some of the comments and suggestions were made by letter, and it is not possible to answer them all individually and in detail. After reviewing the correspondence and talking to most of the individuals involved, I have decided that it will be useful to set straight a number of facts and operational procedures through a circular letter to all experimenters.

First of all, it is quite clear that all members of the operational staff (management, flight crew, ground crew) cooperated fully and worked to the utmost limit of their physical strength and ability, often providing support beyond the call of duty, and even sometimes taking chances on their personal safety. It is also clear that all experimental requirements were fully taken into account. Since these sometimes conflicted, it is inevitable that not everyone could be satisfied at the same time, but flights were scheduled to meet all requirements, even those peculiar to a single experiment. It is a matter of record, of course, that weather and aircraft mechanical problems forced the cancellation of some of these flights.

Our capabilities (particularly aircraft range, frequency of flights, and lead times for flight pattern decisions) were made known before the expedition. Furthermore, the crews are all experienced experts in their field; for example, the pilots are engineers with years of aeronautical research experience, in addition to extensive training in handling all types of aircraft and, in some cases, several years' experience in the arctic.

I am extremely disappointed by the attitude of a number of the scientists who seem to assume that they understand the operational intricacies of a four-engine jet transport. None of the experimenters is qualified to judge whether a particular flight is feasible and what its safe maximum duration can be on a particular day. The following principal factors must be taken into account: present and anticipated weather conditions enroute and at terminal (including alternates); approach and navigation aids; runway conditions; aircraft mechanical status; all effects, such as on fuel load and consumption, of the previous four items; physical condition of both the flight and the ground crews; short- and long-range management problems (e.g., availability of funding for overtime work, contractual agreements, international agreements, etc.).

Typical of the suggestions made to us was that we increase the flight frequency by adding a pilot to our staff. For your information: a) We would need two additional pilots, as well as additional ground support, flight engineers, navigators, etc.; b) Our already limited manpower was further strained by the recall to active duty of one of our pilots; c) Until about two weeks ago, there was a question as to the availability of funding for Session II. Surely you are aware that NASA is operating under the strain of severe cuts in both finances and manpower.

The experimenters are not in a position to comment on the types of problems listed in the above two paragraphs, nor on such other problems as the choice of an operating base. These problems were listed to illustrate some points and to make you aware of a few of the complexities of an airborne expedition. The Expedition Manager takes the ultimate responsibility for such decisions as scheduling and assignment of flight objectives, after due consultation with experimenters and operations personnel. We emphasize that we do need to know the scientific justifications for your flight requirements, so that we have the proper inputs for the overall management and operational decisions.

You may rest assured that the entire team will continue its efforts to get the maximum scientific return within its operational constraints (manpower, funds, aircraft range, etc.). We ask, in return, your understanding and cooperation to help achieve our goals more harmoniously.

[Signature Deleted]
Chief, Airborne Science Office

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Subject: Scientist Team Performance During an Auroral Expedition in NASA's CV-990 Airborne Laboratory - Case 105-9

From: B. A. Gropper

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